WAKE STRUCTURE, LOADING AND VIBRATION OF CYLINDERS: EFFECTS OF SURFACE NONUNIFORMITIES AND UNSTEADY INFLOW

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ABSTRACT

The flow structure from stationary and oscillating cylinders, both with and without surface treatment, has been characterized in steady currents and waves using techniques of high-image-density particle image velocimetry. This quantitative imaging has led to new insight into the quasi-two-dimensional and three-dimensional features of the near-wake, which are intimately related to the loading on the cylinder, for cases where the cylinder is either stationary or elastically mounted. This program has resulted in a total of 46 publications in leading journals and the support of 15 graduate students.

OVERVIEW OF ADVANCES

Detailed insight into the instantaneous and averaged flow structure from stationary and oscillating cylinders is necessary for a full understanding that leads to development of effective control techniques, simplified models for description of the cylinder response, and guidance for large-scale numerical simulations.

For the case of a stationary cylinder, the strong dependence of the near-wake structure on Reynolds number has been characterized in detail. Furthermore, the onset and development of small-scale Kelvin-Helmholtz instabilities in the separating shear layers leading to large-scale Kármán vortex formation has been experimentally defined, for the first time, using quantitative imaging techniques. When the cylinder is in a deep water wave, as opposed to a steady current, the patterns of vortex formation take on a variety of complex forms. Again, the present program represents the first quantitative characterization of these vortex patterns in an experimental setting.

Regarding the three-dimensional structure of the near-wake, use of orthogonal plane, cinema imaging approaches has allowed definition, for the first time, of the space-time volumes of streamwise vorticity that are an inherent feature of the near-wake structure over a broad range of Reynolds numbers. This range extends from the initial onset of vortex formation to much higher values, at which Kelvin-Helmholtz instabilities occur in the separating shear layers.

When the cylinder is subjected to controlled vibration, either at the Kármán frequency or the frequency at which Kelvin-Helmholtz instabilities are formed, it is possible to generate highly coherent vortical structures. These types of control have allowed insight into the optimal response characteristics over the entire near-wake region, as well as the individual, separating shear layers. Quantitative imaging has pointed to fallacies in classical interpretation of streamline patterns, in favor of patterns of vorticity.

In the situation where the cylinder is elastically mounted, such that the vortex formation initiates, and is eventually strongly coupled with, the motion of the cylinder, detailed representations of the near-wake have been attainable using imaging approaches. Design and construction of novel, low mass-damping elastic systems have provided realistic conditions in accord with the ocean environment, and the types of vortex patterns revealed using the imaging approaches has been important in an well-defined, quantitative interpretation of the wake pattern.

In the event that the cylinder has a small-scale surface disturbance(s), it has been demonstrated that large changes in the near-wake structure are attainable. These changes are associated with, in most cases, dramatic alteration of the process of vortex shedding from the cylinder. Innovative analysis techniques, based on quantitative imaging, have involved, for example, global spectral and cross-spectral analysis of the near-wake. In essence, this involves evaluation of spectra and cross-spectra at thousands of points in the near-wake structure via cinema sequences of high resolution PIV images.

Finally, extensive collaboration with the numerical simulation group of Professor George Karniadakis at Brown University has led to enhanced capabilities for computation of complex flow patterns, and a new approach that uses results from quantitative imaging as input to a computation has been advanced.

JOURNAL PUBLICATIONS (IN PRESS/IN PRINT) (Total of 46)

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GRADUATE STUDENTS SUPPORTED (Total of 15)

Student	Degree	Year
Carberry, Josie	Ph.D. (Monash University)	2004
Cetiner, Oksan	Ph.D.	1998
Chyu, C.-K.	Ph.D.	1995
Downes, Keith	M.S.	1999
Gaydon, Matthew	M.S.	1997
Haojun Fu	Ph.D.	2004
Mahir, Necati	Ph.D.	1993
Oshkai, Peter	Ph.D.	2002
Phetkong, Nonglak	M.S.	1996
Saelim, Nattapong	Ph.D.	2003
Towfighi, Joseph	M.S.	1994
Unal, M. Fevzi	Ph.D.	1985
Vorobieff, Peter	Ph.D.	1996
Yingchen Yang	Ph.D.	2005
Zhu, Qing	M.S.	1998

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